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Directional Neutron Detection and TPC Developments and LLNL

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Directional Neutron Detection and TPC Development at LLNL

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Abstract. LLNL is involved with a number of TPC projects spanning basic science to homeland security. This talk outlines the TPC work at LLNL and specifically focuses on the neutron TPC.

1. Introduction

A number of TPC projects are now underway at Lawrence Livermore National Laboratory (LLNL) and there is currently a ramp up in the infrastructure both in equipment and people to support these efforts. In place are high pressure vessels for xenon studies up to 50bar, larger vessels up to 100 litters at 10bar, clean room facilities, extensive electronics development, dedicated lab space and a assortment of radioactive sources.

1.1. Xenon tpc

Xenon is an attractive gas for both neutrino-less double beta decay and dark matter searches because of the low average ionisation energy. In the case of neutrino-less double beta decay this provides better energy resolution, and if the statistical limit could be reached it would only be a few times worse than germanium, but much cheaper and therefore scaleable to much larger detectors. The initial goal of this work at LLNL would be to look at negative ion drift as a method to count charges and try to achieve the statistical limit while maintaining tracking.[1]

1.2. Fission TPC

The development of advanced fission reactors needs better nuclear data to simulate accurately the effects of engineering choices. Cross sections on the major actinides have been identified as a major source of error[2] for the simulations and this project is aimed at reducing the systematic error on neutron induced fission cross sections. The tradition method of using a fission chamber has perhaps reached a limit with respect to reducing systematic errors, and the construction of a TPC to address the systematic errors has now been funded. LLNL is the lead institution for the construction of this TPC that will be run at the LANSCE facility at Los Alamos National Laboratory.

2. Neutron TPC

A detector that can identify neutrons and measure the direction that the neutrons arrived from could be useful for homeland security purposes. The goal of the neutron TPC[3] project is to build such a detector from a hydrogen filled TPC.

The detection principle is very simple. A fast neutron (~2MeV) from a fission source elastically scatters with the hydrogen in the TPC to produce a proton track in the gas. This proton is tracked and the direction of the proton is correlated with the direction of the incoming neutron. Although the kinematics of the scatter blurs the correlation, it only takes about 10 neutron scatters to reduce the cone of uncertainty to the neutron source down to about 16 degrees. The He(n,p)T reaction has also been considered because of the favorable kinematics, but the cross section is about 4.5 less which increases dwell time and cost.

Perhaps one of the most significant tasks in this project is not the physics of the detection process, but the design of a TPC that will be used in the field by non-scientists. The TPC will have to withstand vibration, jolts, temperature swings, possible mis-configuration, abuse and automatic analysis. There are also addition constraints such as weight, size, power consumption, and safety issues in transporting and using the TPC. Each of these items appear to be solvable, but considerable effort will have to go into them and may have lessons that are useful for the design of other TPCs.

A prototype have been built and operated in the lab at LLNL. It has an active volume of about 36 liters and is filled with hydrogen at 2bar absolute. A 83uCi ^{252}Cf source was used as a neutron source as its spectrum is similar to that of other spontaneous fission sources of interest. This source was moved to different locations within and outside the lab to access the performance of the TPC. At 10meters the source could be located with in an hour with the small prototype, and with dwell times of a few hours the source could be located at 20 meters and behind concrete walls. A larger TPC could reduce the dwell times significantly.

3. Electronics

A significant portion of the cost to design and build a TPC is in the electronics. At LLNL we are building a set of electronics with all off-the-shelf components. This is possible because of advances in what is available. For example high speed ADCs with high-density packing, very high performance FPGA and very small discrete components (0201 package). The advantage is that the cost per channel is low even in small quantity. This is good for small or prototype detectors, and it is highly configurable due to the FPGA. The analog portion has been designed and built, and is now in testing. The digital part has been designed and is not in the layout phase. The goal is to have a working set by the end of the year.

4. Conclusion

The TPC effort at LLNL is growing and has something to offer back to the TPC community in electronics development and the accompanying software.

References

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